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Gold precipitation

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THESIS

—ON—

GOLD—

PRECIPITATION

—FOR THE DEGREE OF—

BS

—IN—

—MINE-ENGINEERING—

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1901

S U B J E C T

Electrolytic Precipitation of Gold from Cyanide Solutions as Compared with Precipitation on Zinc Shavings.

I N T R O D U C T I O N

Owing to the large number of low grade mining propositions in this and other countries a process for the treatment of low grade ores is coming more and more into demand.

The most favored and most widely used process for the extraction of gold from low grade ores is the Cyanide Process.

As the complete precipitation of gold from the cyanide solution is one of the most difficult and unsatisfactory features of the process, and believing an investigation of this part of the process to be instructive and beneficial, we have chosen this as the subject of our Thesis.

General Discussion.

A method for the precipitation of gold from weak solutions of cyanide has long been desired and the electrolytic methods, especially the Siemens-Halske Process, claim to meet this want. The process has taken root to a considerable extent in South Africa where much of the ore is so low grade that but for the cheap native labor used it could not be made to pay. The electrolytic methods depend upon the dissociation action of the electric current on an auro-potassium cyanide solution; liberating cyanogen at the positive pole anddepositing metalic gold on the negative pole.

We will confine ourselves almost entirely to the Siemens-Halske Process, which seems to be the one most in favor and most successful. In practical work the precipitation takes place in large iron vats about twenty feet long by eight feet deep by four feet wide. In this process the anodes are sheet iron plates seven by three feet by one-eighth inch thick. The cathodes are of lead, of the same size asthe anodes, stretched on light frames.

The electrodes are set on edge in the iron trough and so arranged, by leaving a space alternately under and above them, that the solution is made to pass first over one plate and then under the next one. A continual circulation of

the solution is thus obtained. It may be asked why it is e necessary to circulate the solution. The following is the reason.

With very dilute solutions as used in the cyanide process the current does not find sufficient of the metalic compound present at the electrodes and consequently part of the current is lost in decomposing water; and for this reason the efficiency of the precipitation is greatly increased by stirring the solution. The electrodes are kept one and one-eighth inches apart. The anodes are covered with canvas in order to avoid short circuits and also to catch the Prussian Blue which is formed as will be explained later. In this process the current density is very small, being variously stated as from .04 to .6 amperes per square foot of cathode surface at an electro motive force of from four to seven volts. It may be well to give here some of the chemical reactions which take place in this process. Theions of potassium-auro cyanide are potassium and Au Cy_2. When the solution is electrolysed the potassium is set free at the lead cathode where it acts an the water forming KOH

$$2H_2O + 2K = 2KOH + H_2$$

At the same time the gold in the double cyanide is displaced and precipitated by the potassium and the nascent hydrogen. Some HCy is formed but is at once neutralized by

the KOH. The $AuCy_2$ which is set free at the iron anode is split up into AuCy and Cy. The Cy unites with the iron forming cyanides which are converted into Prussian Blue ($3FeCy_2 2FeCy_6$) and are oxidised in part, forming ferric oxide. The cyanide of gold is partly precipitated in this ferric oxide unless enough free KCy is present to keep it in solution. There are several requirements which a good cathode should fulfill.

(1) The gold which is deposited ~~and~~ on it should adhere well, so as not to be brushed off by friction of solution or the handling which is necessary.

(2) The material must be capable of being rolled into thin sheets in order to decrease the weight and cost. Large amount of material is not necessary but a large surface is what is required.

(3) The material used for the cathode must be one which is easily and perfectly separated from the gold.

(4) The cathode material must not be more electro-positive than the anode material. This is necessary in order to avoid reverse currents when the current is stopped. We have experienced the evil effects of having poles of the same material in the electrolytic determination of copper; where both electrodes are of platinum. If the current is stopped before the solution is removed some of the copper will deposit on the anode.

(5) The gold should be separable from the cathode without destroying the latter. We will now endeavor to see in how far the lead cathodes chosen by Siemens and Halske will meet these conditions.

With a current of moderate density,- say up to .6 amperes per square foot cathode surface - it is claimed that the deposit is adherent. With a much higher current the deposit is apt to be non-adherent.

We can see very readily that lead meets the requirement in condition number two.

One difficulty with lead is that in thin sheets it is very limber and will not bear its own weight. This difficulty is overcome by stretching it on light wooden frames. These frames can be removed from the trough at any time and new ones inserted without stopping the process. Lead fills the third requirement probably better than any other known substance. It is only necessary to cupel the cathodes in order to recover the gold.

Lead also meets the fourth requirement when iron is anode.

It will be seen that lead only partially meets the fifth requirement. The cathode is of course destroyed, but the lead is recovered in the form of litharge which may be reduced to metalic lead or sent to the market as such.

There is an objection to the iron plates which are used for the anodes. This objection is that they are consumed

to some extent by the KCy and consume KCy. They form with KCy Prussian Blue which may be collected and boiled with KOH, by which means the KCy is regenerated if desired. The cost of the KOH used and expense of treatment would probably be more than the worth of KCy regenerated.

Probably we have discussed the Siemens-Halske process sufficiently to give an idea of its working, and will now give a brief outline of the method of precipitation of gold ~~and~~ on zinc shavings. The working and general features of the process are too well known to need any detailed description. The freshly cut zinc shavings or turnings are put into the precipitation boxes and the current of cyanide solution of gold is run through them. The gold is precipitated on the shavings. The exact reactions which take place are not known with any degree of certainty. For a long time it was thought that it was a simple substitution of the zinc for the gold, as expressed by the following equation.

$$2KAuCy_2 + Zn = K_2ZnCy_4 + 2Au$$

Though this reaction may go on to some extent, it by no means is the only one. We know this from presence of compounds which we find in the solution after passing through the zinc boxes which were not there before; and by the presence of hydrogen on the zinc and odor of HCy coming from the zinc boxes; also by the enormous consumption of zinc

and KCy. According to the above equation one ounce of zinc should precipitate or replace six ounces of gold, while it actually takes an an average of ten ounces of zinc to replace six ounces of gold. One explanation of this is that other metals such as silver, copper, mercury, antimony, lead and arsenic and also KOH and NaOH dissolve the zinc with the evolution of hydrogen. It has been suggested that the following equation more nearly represents one of the principal reactions.

$$2KAuCy_2 + 2Zn + 2H_2O = 2KOH + H_2 + 2ZnCy_2 + 2Au$$

This would require the replacement of the potassium ions by zinc according tp the equation.

$$2(K + AuCy_2) + Zn = (Zn + 2AuCy_2) + 2K$$

followed by a rearrangement of the molecule of zinc gold cyanide and the replacement of the gold by another atom of zinc.

The hydrogen which is set free in the second reaction would form on the sheet zinc and prevent further action; while in the case of zinc shavings the hydrogen does not adhere well to the sharp edges. A thin layer of $ZnCy_2$ forming on the zinc is another explanation of the poor action of sheet zinc and the necessity of an excess of free KCy . In the absence of KCy the reaction may go on as follows

$$4ZnCy_2 + 4KOH = 2ZnCy_2 + Zn_2(OK)_2 + 2H_2O$$

If KCy had been present this reaction would have been completed, thus,-

$$ZnCy_2 + 2KCy = K_2ZnCy_4$$

Pure zinc does not act so readily as impure, on account of the galvanic action of the impurity with the zinc. The gold is supposed to form a couple with the zinc and hasten the action after it has once started.

This electrolytic action may decompose water and account for the hydrogen formed as follows:-

$$Zn + 2H_2O = Zn(OH)_2 + H_2$$

The $Zn(OH)_2$ formed as above may dissolve in KCy, thus:- $Zn(OH)_2 + 4KCy = K_2ZnCy_4 + 2KOH$. But this KOH will at once act on the metalic zinc and form potassium zincate.

$$Zn + 2KOH = Zn(OK)_2 + H_2$$

Then this zincate is at once dissolved by KCy according to the following equation.-

$$Zn(OK)_2 + 4KCy + 2H_2O = K_2ZnCy_4 \text{ ———}$$

which seems to be an endless reaction.

It has been pretty conclusively proven that at least some of the foregoing equations take place. So it may be seen that the reactions which take place are not the simple replacements which they were formerly thought to be. If the simple replacement of gold by zinc were the only reaction the gold would be deposited as a yellow or greenish coating of metalic gold on the zinc; but it more often is

in the form of a black slime. Some think this slime is zinc gold cyanide because on dissolving in H_2SO_4 free HCy is expelled.

We will now state the advantages and disadvantages of the Siemens-Halske Process and the ordinary zinc precipitation process. It is claimed that a solution containing .03% KCy will dissolve the gold as perfectly from some ores, as a solution containing .3%, but will require a somewhat longer time. The ordinary zinc precipitation method will not extract gold advantageously from solutions much weaker than .3%, so if we had no other method of precipitation it would be necessary to use this strong solution whether the ore required it or not. The electrolytic methods seldom use a solution stronger than .1%.

The advantages claimed for the Siemens-Halske Process are:-

(1) Easy and perfect extraction from both weak and strong solutions.

(2) For this reason weak solutions can be used for solution of gold.

(3) The Prussian Blue can be cheaply treated to give pure KCy.

(4) Great saving in consumption of KCy.

(5) Process is very clean and is continuous.

(6) Cost is low,being about 3 cents per ton of ore.

(7) Higher grade bullion than given by zinc.

The disvantages claimed against the process are:-

(1) Large initial cost of plant.

(2) A 5% royalty is charged on the process.

(3) Necessity of power for dynamos and expense of hiring an experienced electrician to look after the plant.

A great difficulty of the process is the enormous resistance offered by the weak solutions to the passage of the electric current. This may be partially overcome by increasing the size of anode and cathode and circulating the solution.

The objections to the zinc Precipitation Process are:-

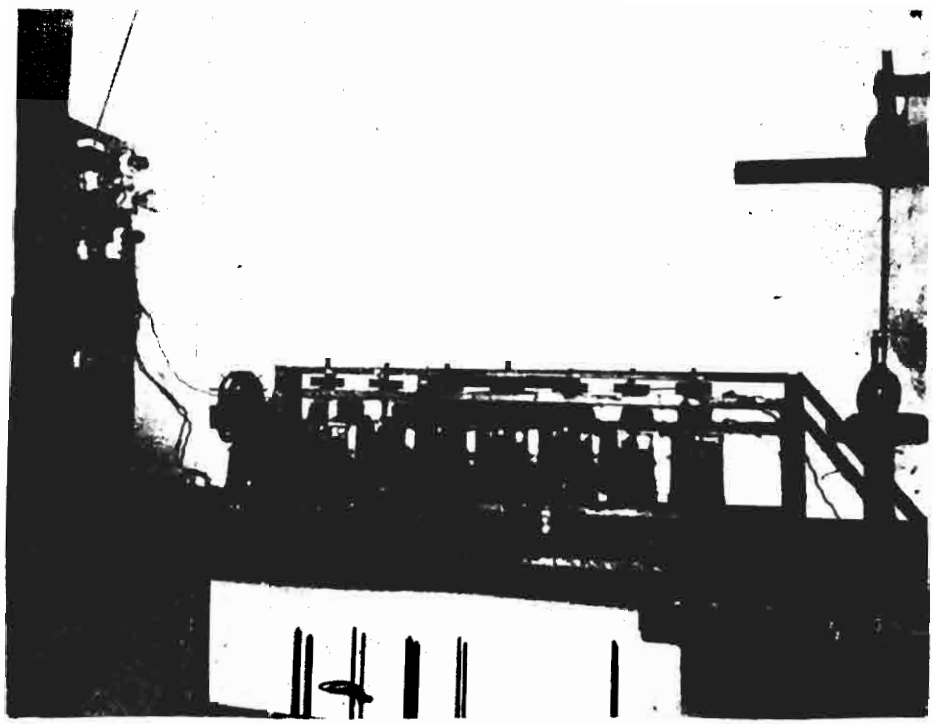
(1) Great consumption of zinc compared with the amount of gold precipitated.

(2) Great destruction of KCy.

(3) Strong solutions required.

(4) Great difficulty of separating the gold from zinc residues.

(5) Failure in some cases to precipitate gold.



Description of Apparatus Used.

I. Apparatus for Electrical Tests.

The method of stirring the Cyanide solution in practice, is, as stated before, to slowly circulate the solution through long troughs. For a laboratory test, where only about 500 to 1000 cubic centimeters of solution can be used on account of the cost of the auro cyanide, this would not be practicable. We constructed an apparatus by means of which the solution can be continuously stirred for any length of time, and so arranged that we can run seven determinations at once. The stirring is accomplished by simply revolving the cathode. The apparatus is shown in elevation in Fig.I and in plan in Fig.II and a photograph is given in Plate I. The apparatus consists of a motor, and auxilliary pulley to reduce the speed, and the main frame holding the cathodes. The motor is a direct current fan motor requiring 110 volts and .75 amperes. A small pulley was fastened to the shaft of the motor and a belt runs from this pulley to the auxilliary pulley which is seven inches in diameter and has grooves for two belts. The pulley is revolved in a horizontal plane being supported by a suitable frame. The belts are of carpenter's chalk line, which we found to wear very well. A second belt runs from the large pulley to seven small pulleys of three and a half inches diameter, which are on the shafts (e) that revolve the cathodes. The shafts with the revolving cathodes are held in

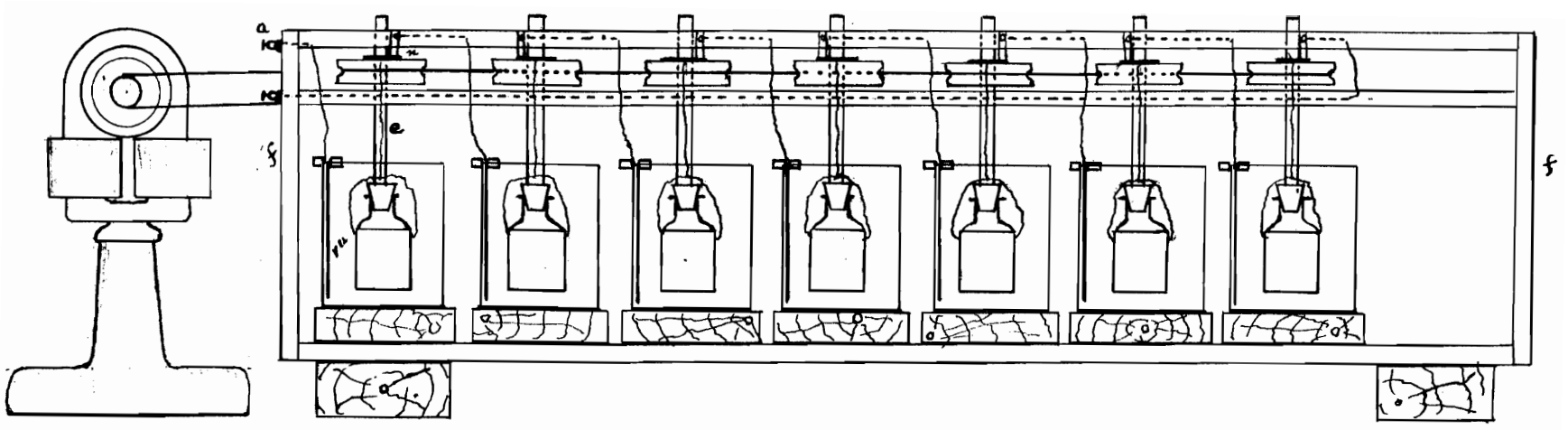


Fig. I.

a vertical position by a frame (f). The shafts are seven inches long and one half inch diameter. The lower end of each shaft was forced into a one hole rubber stopper. This stopper was pushed into the neck of a round salt bottle two inches deep and two inches diameter and the bottle securely tied to the shaft just above the stopper. The bottles are thus held firmly to the shaft and revolve with it.

The cathode, which in four cases of the five is of lead foil, is tightly wrapped around the bottle and fastened by doubling the edges together. The cathode is two inches wide by six inches long.

The anode is a piece of sheet iron bent to fit the side of the vessel which contains the electrolyte, and tightly clamped to the side of the vessel. In some of the experiments we enclosed the anodes in canvas bags.

Electrical Connections.- We had our switch board and connections so arranged that we could run from school dynamo, school storage batteries, or town dynamo by simply changing connections on switch board and adjusting the variable resistance. Got the current to run through our solution by a shunt from the motor line. The current is run through a variable resistance to ammeter, then to binding past (a). From here a wire carries it to the iron anode "ru", then it passes through the auro-cyanide solution to the lead cathode. From the cathode two small wires laid in

Plan.

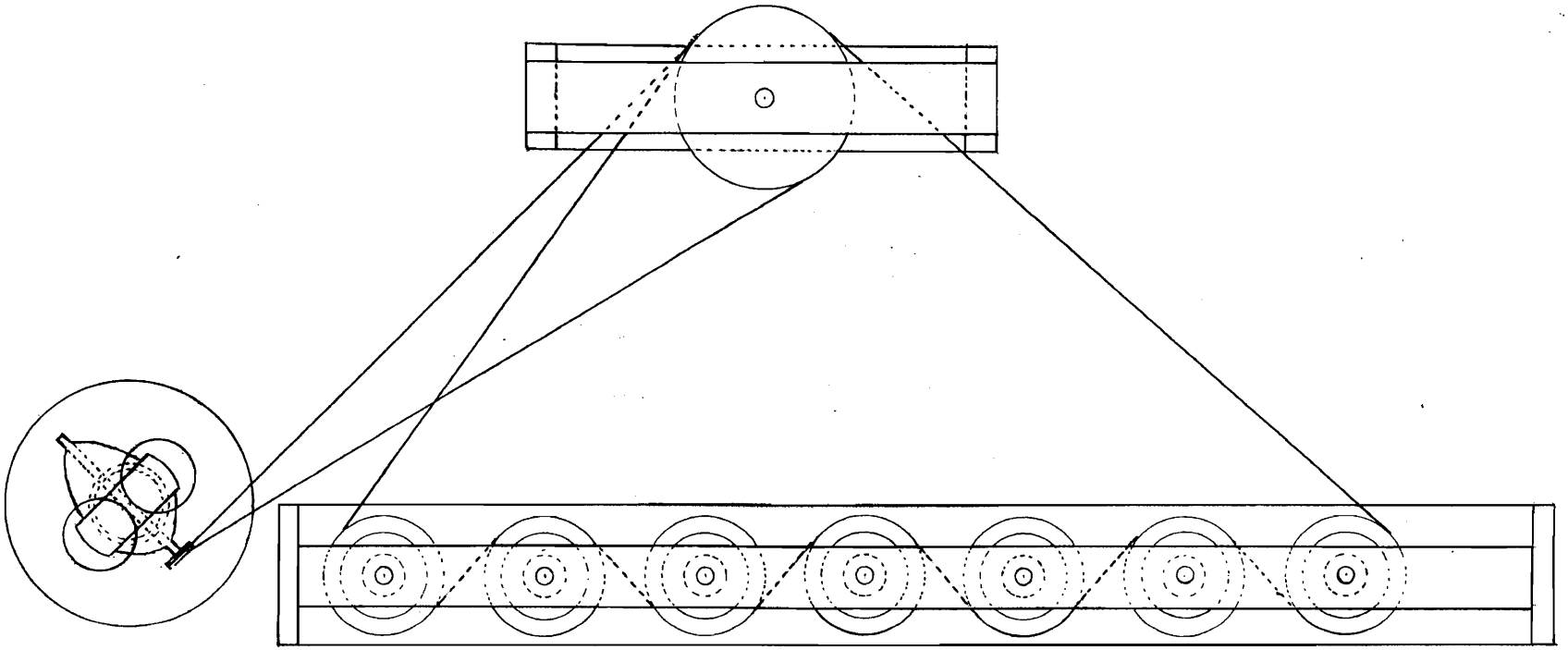


Fig II.

a groove in the shaft lead it through the pulley to a copper washer "n" fastened on the upper side of the pulley. A brush made of metal strips, something like the copper brushes on dynamos, rubs against the copper washer and makes good connections. From this brush a wire carries the current to the next iron anode and so on through the series of seven cells, the wire from the last brush returning to another binding post. It has been seen that the cells are connected in series, the same current flowing through all and the drop in volts depending on the resistance of each cell.

The vessels which contain the electrolyte are common glass battery jars five and one-fourth inches high and four and a half inches in diameter.

The solution of auro-potassium cyanide is put in to the jars, the jars raised until the solution covers the cathode, the current turned on and cathodes started to revolving.

II. Apparatus for Zinc Tests.

This apparatus is a very simple affair. The zinc turnings, made by wrapping sheet zinc on a wooden cylinder and turning in a lathe, are put into a glass tube about three feet long and seven-eighths of an inch in diameter. A one hole rubber stopper is tightly fitted into each end of the tube. The tubes are held in a vertical position by clamps.

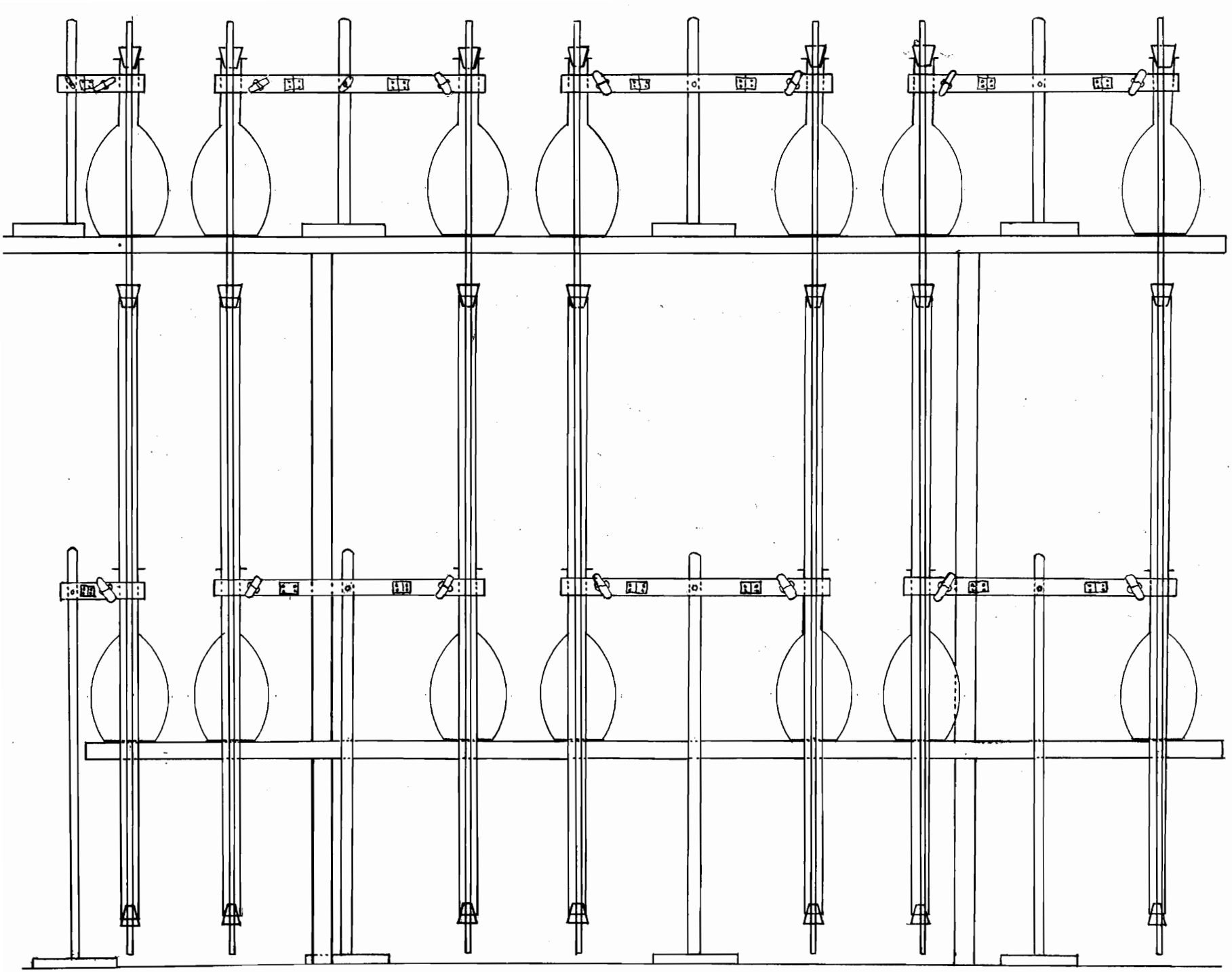


Fig 3.

The solution of auro-potassium cyanide is placed in flasks which are set on a shelf above the top of the zinc tubes.

A glass tube with a rubber joint runs from the flask to the lower end of the zinc tube and through the one hole stopper. Then a tube passes out through the upper one hole stopper and empties into another flask. The solution runs from the upper flask through the connecting tube by syphan action, enters at the lower end of the zinc tube and rises through the zinc turnings until it overflows through the tube in the upper end into the receiving flask. The flow of the solution is regulated by a screw cock on the rubber joint in the inlet tube.

When the solution has all run from the upper flask, it is poured back into it through a funnel and run through this way as many times as desired.

Electrolytic Test #1.

The purpose of this test was to determine how well the gold would precipitate from neutral solutions of different strengths, and compare with zinc precipitation under the same conditions. Used lead cathode of twelve square inches surface. Strengths of solutions can be seen by reference to accompanying table. We kept a fairly constant current of .05 amperes which would be equal to .6 amperes per square foot cathode. About two hours after starting the

Electrolytic Test #1.

No.	Strength Solution	Weight Salt Taken	Assay of Foil	Assay of Ppt.
1	.005%	.025 Gr.	.00529 Gr.	.00666 Gr.
2	.01 "	.05 "	.01254 "	.00902 "
3	.02 "	.1 "	.03376 "	.01525 "
4	.04 "	.2 "	.10506 "	.01272 "
5	.06 "	.3 "	.13175 "	.02674 "
6	.08 "	.4 "	.17758 "	.04642 "
7	.1 "	.5 "	.10920 "	.04506

Assay of Solution	Sum of Assays	Per Cent Au on Foil	Per Cent Au in Ppt.	Total % Extracted
.0004 Gr	.01235 Gr	42.83%	53.92%	96.75%
-- - - "	.02159 "	58.08"	41.77"	99.85"
.00002 "	.04903 "	68.85"	31.10"	99.95"
.00007 "	.11785 "	89.14"	10.79"	99.93"
.00009 "	.15849 "	83.12"	16.81"	99.93"
.00043 "	.22443 "	79.12"	20.72	99.84"
.00021 "	.15447 "	Pt.lost	- - --	-- - - -

drop in volts in each cell was as follows.

#1 - 11 volts. It will be seen that the drop decreases.
#2 - 6 " Very regularly with the increase in
#3 - 7 " strength of the solution.
#4 - 5 " In the four stronger solutions
#5 - 4 " Prussian Blue began to form in
#6 - 3 1/2 " about an hour after starting.
#7 - 4 1/2 " The amount of KCy liberated by the decomposition of the auro cyanide was sufficient to form the Prussian Blue, while in the weaker solutions it formed very slowly and never did form to any great extent, but a heavy brown precipitate of ferric oxide formed. After about twelve hours run the resistance of the cells increased.

Ran twenty-four hours. Then stopped current and detached the bottles and set on filter paper to dry. Filtered the electrolyte and dried the precipitate on the filter paper. Evaporated solution to dryness in lead pans. Scarified precipitate, residue from solution, and lead cathodes. Assay of each given in table. The percent extraction is calculated on the sum of these three assays. According to assays run on the salt used in this experiment it was probably $KAuCy_2$ while the salt used in the following experiments conformed more closely to the formula $KAuCy_4 .3H_2O$. The salt even in the same bottles did not run evenly; so

Zinc Test #1.

No.	Strength Solution	Weight Salt Taken	Assay of Zn Slime	Assay of Solution.	Sum of Assays	Per Cent Extracted
1	.005%	.025 Gr	.00903 Gr	.00030 Gr.	.00938 Gr	96.80%
2	.01 "	.05 "	.01733 "	.00149 "	.01882 "	92.08"
3	.02 "	.1 "	.03068 "	.00042 "	.03110 "	98.65"
4	.04 "	.2 "	.08679 "	.00054 "	.08733 "	99.38"
5	.06 "	.3 "	.10860 "	.02548 "	.13408 "	80.99"
6	.08 "	.4 "	.12096 "	.00964 "	.13060 "	92.64"
7	.1 "	.5 "	.20099 "	.01154 "	.21253 "	94.09"

we concluded that either the salt was not uniform in its composition or it was to some extent volatile.

Zinc Test #1.

The purpose of this experiment was to compare with Electrolytic Test #1. Used same strength of solutions as used in that test.

Allowed the solutions to slowly filter through about eighteen inches fresh zinc turnings for about twenty-four hours. Then took down the tubes and washed the zinc. Dissolved the zinc in dilute acid ($2H_2SO_4 + 1HNO_3$). Filtered and washed the resulting slime. Dried and scarified it. Evaporated and assayed solution which had run through the zinc turnings. Result of assays can be seen in the table.

Electrolytic Test #2.

The solutions in this test are like those used in Electrolytic #1 and zinc #1 except each cell has .5 gram KCy added to it.

Used about the same current as in first one. In this test covered the anodes with canvas. Notice the extremely small amount of gold in the precipitate as compared with the large amount in Electrolytic #1. Solutions became colored by Prussian Blue very soon after starting. One hour after starting the drop in volts in each cell was as follows:-

Electrolytic Test #2.

No.	Strength Solution	Weight of Salt Taken	Assay of Foil	Assay of Ppt.
1	.005%	.025 Gr.	.03874 Gr.	.0001 Gr
2	.01 "	.05 "	.01232 "	.00004 "
3	.02 "	.1 "	.03770 "	.00061 "
4	.04 "	.2 "	.06970 "	.00028 "
5	.06 "	.3 "	.10588 "	.00052 "
6	.08 "	.4 "	- - - -	.00068 "
7	.10 "	.5 "	.17121 "	.00041 "

Assay of Solution	Sum of Assays	Per Cent Au on Foil	Per Cent Au in Ppt.	Total % Extracted
.01038 Gr	Salted	Salted	-- - --	-- - - - -
.00276 "	.01512 Gr	81.48%	.27%	81.75%
.00180 "	.04011 "	93.99"	1.52"	95.51"
.00365 "	.07363 "	94.66"	.38"	95.04"
.00822 "	.11462 "	73.21"	.36"	73.57"
.01669 "	- - - -	- - - -	- - -- -	- - - - -
- - - -	- - - -	- - -	- -- - -	- - - - -

#1 - 5 volts

#2 - 5 "

#3 - 5 "

#4 - 5 "

#5 - 6 "

#6 - 4 "

#7 - 4 "

(About 8 hours after starting drop was

#1-10 volts

#2-6 "

#3-7 "

#4-5 "

#5-6 "

#6-5 "

#7-5 "

Ran experiment about 18 hours The Prussian Blue had mostly collected on the bags. Assayed as before. See table for results.

Zinc Test #2.

This test was to compare with Electrolytic #2 and Zinc #1. Used same solutions as in Electrolytic #2. Ran about twenty-four hours. Dissolved zinc and assayed as in Zinc #1. See table for results .

Electrolytic Test #3.

We intended to determine by this experiment the best current density to use. To vary the current density we varied the area of the cathode. .005 ampere flowed through the circuit. The areas of the cathodes and the calculated current densities are shown in the table. Very poor extraction was obtained in all cases. We used a neutral solution of .04% for all tests. Drop in volts one and one half hours after starting.

#1 - 1 volt Ran about 24 hours and

#2 - 1 " assayed as before. We lost the

#3 - 1

Zinc Test #2

No.	Strength Solution	Weight Salt Taken	Assay of Zn Slime	Assay of Solution	Sum of Assays	Per Cent Extracted
1	.005%	.025 Gr	.00628 Gr	.00020 Gr	.00648 Gr	96.91%
2	.01 "	.05 "	.01060 "	.00012 "	.01072 "	98.97"
3	.02 "	.1 "	.03295 "	.00380 "	.03675 "	89.66"
4	.04 "	.2 "	.06962 "	.00582 "	.07544 "	92.28"
5	.06 "	.3 "	.10350 "	.01090 "	.11440 "	90.48"
6	.08 "	.4 "	.13478 "	.00483 "	.13961 "	96.54"
7	.1 "	.5 "	.17758 "	.01278 "	.19036 "	93.28"

Electrolytic Test #3.

No.	Area of Cathode	Strength Current	Assay of Foil	Assay of Ppt.
1	1.68 sq.in.	.42 Amp.	.00692 Gr.	.00071 Gr.
2	3.36 " "	.21 "	.00590 "	.00078 "
3	5.04 " "	.14 "	.01020 "	.00130 "
4	6.72 " "	.105 "	.00818 "	.00116 "
5	8.40 " "	.084 "	.01100 "	.00088 "
6	10.08 " "	.07 "	.01300 "	.00146 "
7	12.00 " "	.06 "	.01280 "	.00036 "

Assay of Solution	Sum of Assays	Percent Au on Foil	Percent Au in Ppt.	Total % Extracted.
.06501 Gr.	.07264 Gr	9.52%	.95%	10.47%
.06596 "	" "	8.12"	1.07"	9.19"
.06114 "	" "	14.41"	.70"	15.11"
.06330 "	" "	14.04"	1.59"	15.63"
.06076 "	" "	15.11"	1.21"	16.32"
.05818 "	" "	17.89"	2.01"	19.90"
.05948 "	" "	17.62"	.63"	18.25"

#4 - 1 volt / Solutions in this run so we got
#5 - 1 " / percentage extraction by calculating
#6 - 1/2 (previous averages.
#7 - 1 " (

Electrolytic Test #4.

This test was intended to determine best time. Used .04% solutions without any free KCy. Used 12 square inches cathode surface and .05 amperes. One hour after starting drop in volts was.

#1 - 3 volts (Ferric oxide for ed to small extent. Used
#2 - 5 " (canvas on anodes. Longest time was 42 hrs. Took
#3 - 5 " (one cell off every 6 hours. See table for
#4 - 5 " (results of run.
#5 - 5 " (
#6 - 5 " (
#7 - 4 "

Electrolytic Test #5.

In this test we used amalgamated copper foil for cathodes in place of the lead foil. Used same strength of solution as in Electrolytic #1.

Had 12 square inches cathode surface.

Drop in volts 2 hours after starting.

#1 - 5 volts (Ran 24 hours. A peculiar fact was that no
#2 - 5 " (Prussian Blue whatever could be seen in even

Electrolytic Test #4.

No.	Time	Assay of Foil	Assay of Ppt.	Assay Solution
1	42 hrs.	.07289 Gr	.00191 Gr	.00038 Gr
2	36 "	.05937 "	.01035 "	.00135 "
3	30 "	.05943 "	.00220 "	.00082 "
4	24 "	.07432 "	.00121 "	.00020 "
5	18 "	.06713 "	.00290 "	.00287 "
6	12 "	.05632 "	.00132 "	.00502 "
7	6 "	.05323 "	.00073 "	.01470 "

Sum of Assays	Per Cent Au on Foil	Per Cent Au in Ppt.	Total % Extracted
.07498 Gr	97.21%	2.55%	99.76%
.07107 "	83.53"	4.57"	98.10"
.06245 "	95.16"	3.52"	98.68"
.07584 "	97.99"	1.74%	99.73"
.07290 "	92.09"	3.97"	96.06"
.06266 "	89.91"	2.10"	92.01"
.06866 "	77.53"	1.06"	78.59"

Electrolytic Test #5.

No.	Strength Solution	Weight Salt Taken	Assay of Foil.	Assay of Ppt.
1	.005%	.025 Gr.	.00853 Gr.	.00038 Gr.
2	.01 "	.05 "	.01729 "	.00080 "
3	.02 "	.L "	.03417 "	.00170 "
4	.04 "	.2 "	.07050 "	.00104 "
5	.06 "	.3 "	.07658 "	.00070 "
6	.08 "	.4 "	.13668 "	.00140 "
7	.1 "	.5 "	.17141 "	.00201 "

Assay of Solution	Sum of Assays	Per Cent Au on Foil	Per Cent Au in Ppt.	Total % Extracted
.00017 Gr.	.00908 Gr.	94.03%	4.19%	98.22%
.00007 "	.01816 "	93.55"	4.40"	97.95"
.00045 "	.03632 "	94.08"	4.68"	98.76"
.00110 "	.07264 "	97.05"	1.43"	98.48"
.00168 "	.07896 "	96.98"	.88"	97.86"
.00720 "	.14528 "	94.07"	.96"	95.03"
.00818 "	.18161 "	94.49"	1.10"	95.59"

Zinc Test #3.

No.	Strength Solution	Weight Salt Taken	Assay of Zn Slime	Assay of Solution.
1	.005%	.025 Gr	.00830 Gr	Trace
2	.01 "	.05 "	.01666 "	Trace
3	.02 "	.1 "	.03940 "	Trace
4	.04 "	.2 "	.07731 "	.00003 Gr
5	.06 "	.3 "	.11441 "	.00004 "
6	.08 "	.4 "	.16486 "	.00004 "
7	.1 "	.5 "	.19936 "	.00005 "

Sum of Assays	Per Cent Extracted
.00830 Gr	99.99+ %
.01666 "	99.99+ "
.03940 "	99.99+ "
.07734 "	99.96 "
.11445 "	99.96 "
.16490 "	99.97 "
.19941 "	99.97 "

#3 - 5 volts (the strongest solutions, but large amount of
#4 - 3 " (ferric oxide was formed in all of the cells.
#5 - 3 " (No canvas bags were used on the cathodes
#6 - 2 ") which seems to show that nore ferric oxide
#7 - 2 " (forms more readily when they are not used.

The copper was dissolved in nitric acid. $Pb(C_2H_3O_2)_2$ was added to the solution and then a few drops of sulphuric acid. The lead sulphate was dried and assayed. The result of run may be seen in the table.

Zinc Test #3.

In this test a 10% solution of lead acetate was run through the zinc tubes until the zinc became dark from precipitated lead. Then drained off the solution and turned on the solution of potassium-auro cyanide. The same strengths of solutions were used as in Zinc #1. The lead and zinc form a couple and an electrolytic action is set up, which aids in precipitating the gold. Ran the test about twenty-four hours.

Conclusions.

As the result of our experiments it is natural that we should draw certain conclusions. In the descriptions of the experiments we have not endeavored to make any comparisons nor draw any conclusions. By using the pure auro-potassium cyanide, we thought it would be possible to get more accurate comparisons than by getting the gold solu-

tion by leaching a gold ore, of uncertain and unknown composition, with KCy. Unfortunately the dealer sent us a salt which was not the $KAuCy_2$ which we are supposed to get when we treat a gold ore with KCy.

One thing which was very evident in the Electrolytic #1, was that with a neutral solution a large precipitate of ferric oxide was formed which carried down a large percentage of the gold cyanide. This must have been the reason that the precipitate carried so much gold. Comparing this test with Electrolytic #2 where we had an excess of free KCy we see that in the latter where Prussian Blue was formed only a very small amount of gold was found in the precipitate.

Comparing Electrolytic #1 with Zinc #1 we see that with a neutral solution the electrolytic methods beats the zinc extraction by about 6%. Comparing Electrolytic #2 and Zinc #2 we see that the zinc extraction is about 9% better than the electrolytic. It will be remembered that in this case we had a slight excess of free KCy. The Electrolytic #3 was intended to determine strength of current but we could not make the cathodes large enough with our apparatus so there was nothing proven by the experiment.

Electrolytic #4 shows that it does not necessiarly require a very long time to get a very good extraction. Eighteen hours to thirty-six hours gave as good an extrac-

tion as the forty-two hour run.

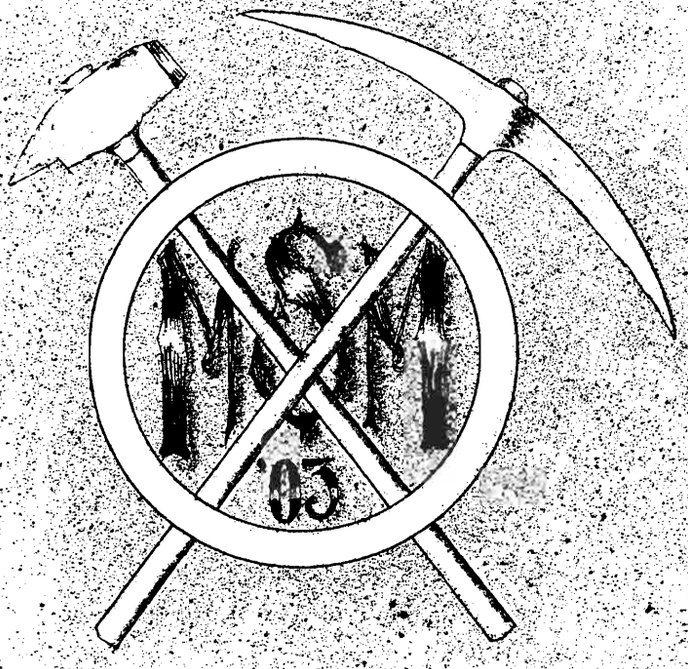
Electrolytic #5 is a test by its self. It seems to give a very good extraction but it is much more difficult to separate the gold from the copper and mercury than from the lead.

Zinc #3 is the best extraction we had. In this test we got practically 100% extracted even with the weakest neutral solutions. We would say from our experiments that if lead acetate does not add too great an item of expense it is by far the perferable method for weak solutions. If the lead acetate is too expensive or hard to get and the ore requires only a very weak solution of KCy the electrolytic method may be preferable to the common zinc method; but if the ore requires even a moderate excess of KCy in order to extract its gold, we think that the common zinc precip itation method will give the better satisfaction.

Of the two electrolytic methods which we tested we prefer the Siemens-Halske as it gives about as good extraction and the gold is so much more easily separated from the cathode material. We found it very beneficial to use the canvas bags around the anodes as they collected the precipitate formed and seemed thus to prevent the gold being strown down in the precipitate. Again we will say that as far as perfection of extraction is concerned, the Lead-Zinc Couple or Betty-Carter Process is far ahead of anything we tried.

Of course in practice this method may not be so desirable as it here appears on account of throwing down the base metals.

A good knowledge of results can only be obtained by a careful study and comparison of the tables and conditions under which experiments were made.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